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Wire Accelerated Life Cycle Tester

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Capstone Senior Design Project

Report #2

Project Title: Wire Accelerated Life Cycle Tester

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1 Acknowledgements

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- Jeremy Schaffer
- Brian Minnich
- Larry Kay
- Fort Wayne Metals Metlab

We also would not have been able to complete this project if it were not due to the continued support of Mike Schumm and Kenny Steven from Best Parts. Throughout the whole project, these two have been a huge benefit. They worked with us hand in hand in the manufacturing of all our parts, giving us guidance in what would make the parts easier and cheaper during the manufacturing process. One of the biggest benefits of this project for our group was being so closely involved in the manufacturing process of the parts that were designed.

In addition to the people listed above, we would also like to thank Andrew Hill from 80/20, Inc. He was very helpful in the purchase of their product as well as the delivery of it.

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In addition to our advisors for our project, we would like to thank the entire IPFW Department of Engineering faculty for their insight and guidance during our presentations.

Without the support of all the individuals listed above, this project would have not been possible.

2 Abstract

Fort Wayne Metals is interested in developing a new machine to experimentally test fatigue strength of various metal wiring manufactured by their company. The test rotates a wire while arced so that the peak experiences equal amount of tension and compressive loading until the sample breaks from cyclic loading. The wiring has a wide range of applications from industrial cable used in military helicopters to a more apparent use, medical wiring which includes neurostimulation and cardiac lead wire.

The company has specifically requested the design of this system have more functional components integrated unlike their more primitive machines currently in use. This includes, but is not limited to, an integrated bath design to wet test samples in a circulating saline solution with a calibrated way to adjust the arc dimensions of the sample.

Electronically, Fort Wayne Metals also requests a functional user interface to program test duration in terms of cycle count that the wire experiences. Likewise, the end design requires a form of break detection if the sample fails before the test duration is completed and an appropriate method of kill switching the motor as well as recording the cycle count at time of failure. Additional specific considerations regarding test conditions and housing have also been specified by the company.

This document will discuss all requirements applied to the evolution of designs conducted by IPFW's senior capstone design team during the fall months of 2012. Particular elaboration regarding design evaluation, cost analysis, and manufacturing plans are also taken into consideration and documented.

3 Last Semester's Design

During last semester, our team went through the process of designing the wire life cycle tester. The purpose of this machine was to decrease testing time as well as to make the user interface more easily useable. Figure 3.1 and Figure 3.2 illustrate last semester's design.

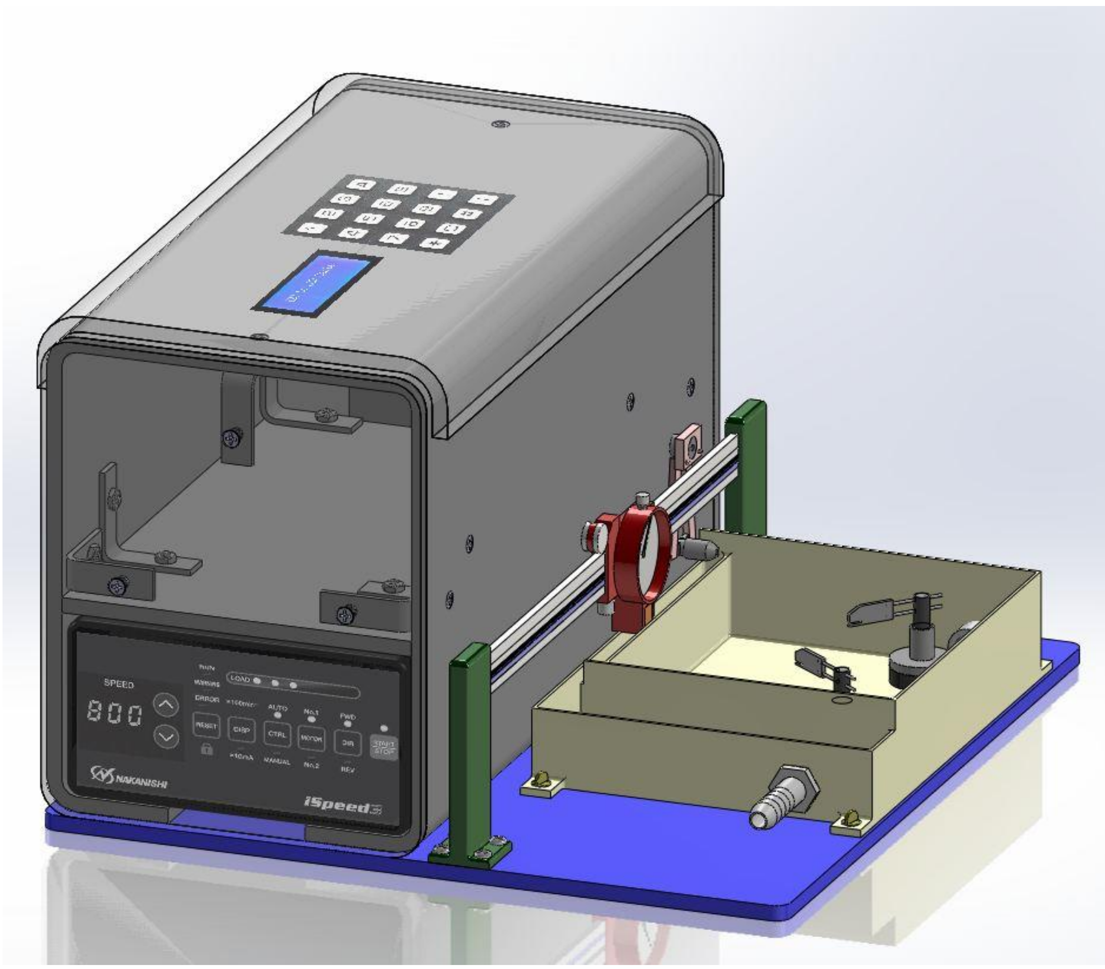

Figure 3.1: Front Isometric View of Last Semester Design

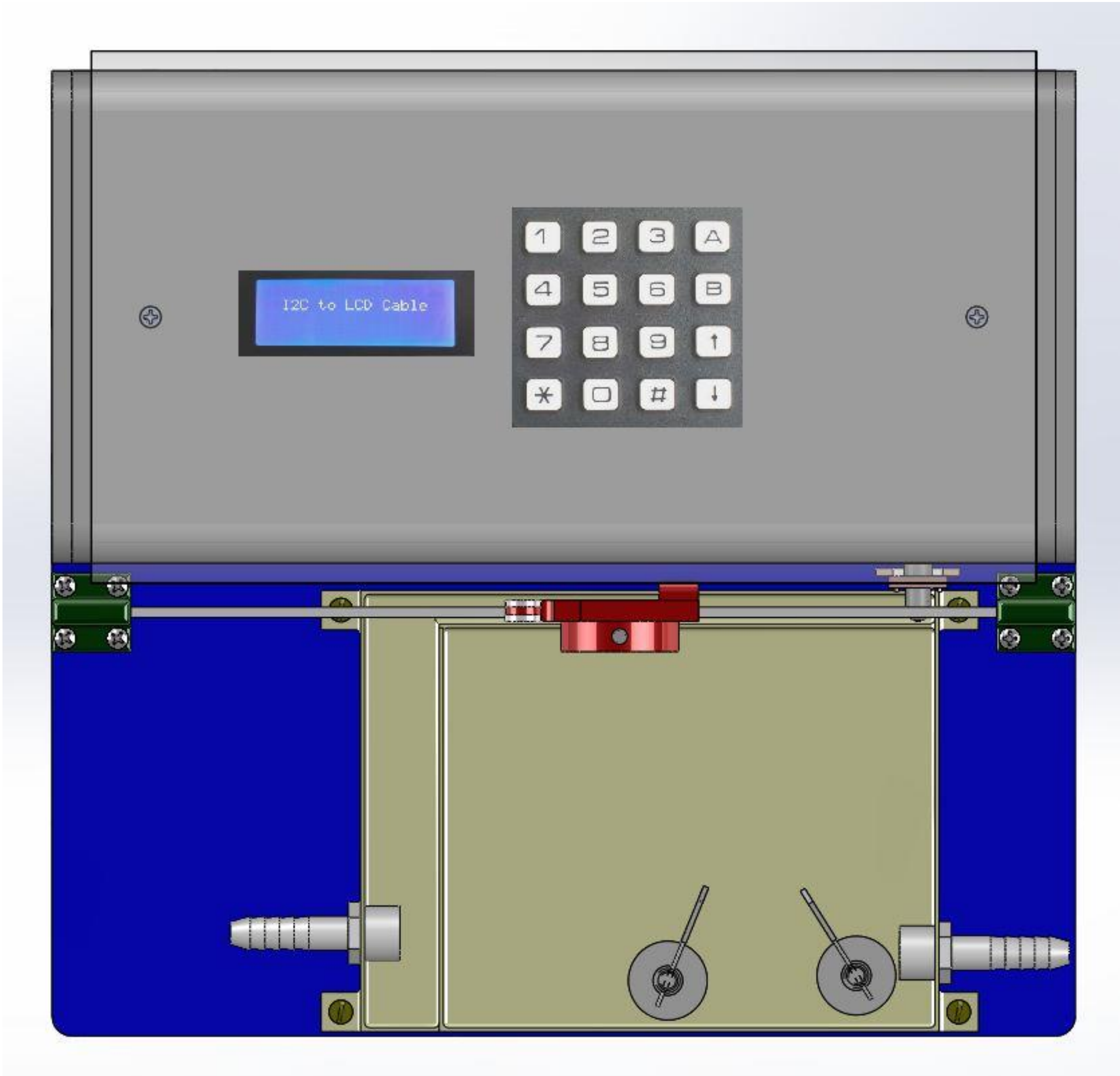

Figure 3.2: Top View of Last Semester's Design

3.1 Requirements & Specifications

The rotary wire fatigue tester being designed must meet a list of very specific design specifications designated by the company sponsor, Fort Wayne Metals (FWM). Certain design stipulations have been previously discussed with FWM engineering department as more important than others they wish to aim for in a final product, but do not require for an acceptable design.

- Testing Conditions
    - Dry Testing: Assume ambient room temperature of 20-25°C
    - Wet Testing: Preferred temperature range of 20-50°C
        - Mediums: RO water, up to 5% saline solution, and other variable mediums with steady flow rate integrated into the housing / test platform
- Test Sample Specifications
    - Wire Diameter: 0.001” to 0.015”
    - Test Arc Center Distance: 0.12” to 6”
    - Test Arc Height: 0.10” to 5”
    - Cycle: Up to 200 million cycles
- Electronics & Controls
    - Cycle Counting: Digital readout with cycle count as well as test start/end date/time
    - Motor Speed Control: Variable speed control from 1k to 100k RPM in 1k increments
        - Motor has an initial ramping function as not to jerk the test sample at startup
    - Controlled Programming: Ability to enter desired test duration with machine kill switch once programmed duration is reached
    - Break Detection: Automatic test kill switch upon sample fracture
        - Must work in both wet and dry test conditions
    - Power supplied is 120Vrms, 15Amps, 60Hz.

3.2 Given Parameters

Fort Wayne Metals has also supplied us with some fixed parameters that the rotating fatigue tester must meet. These parameters cannot be changed or varied in any way so that Fort Wayne Metals will be satisfied with the new design. A list of these design parameters can be seen below.

- Budget: $10,000 for prototyping
- Operating Conditions:
  - Must operate in ambient temperature of 20-25 °C
  - Capable of wet or dry testing
  - Must run continuously months
- Controls:
  - On/Off
  - Speed Control
- Horizontal operation
- Wire Supports
  - Quick set up
  - Low coefficient of friction
  - Corrosion proof
  - Hold position well
  - Low conductivity
- Machine Adjustability

Additionally to the list of design requirements and specifications listed above, the company has also requested certain design stipulations be factored into the housing of the final product. Based upon the two testing models they currently use, the company prefers a horizontal test setup as implemented in the Positool Technologies design.

3.3 Design Variables

- Motor Design
- Microcontroller
- Communication style with the motor
- Chuck design
- Power Transmission
- Wire Support Towers
- Bath Design
- Materials
- Packaging

3.4 Design Revisions

After the first semester, the design was modified slightly for ease of assembly and manufacture. With further evaluation of the first design, it was decided to change the overall packaging of the system. The overall function of the machine of stayed the same. There were some modifications made to the packaging of the machine as well as some of the more detailed aspects of the system. The original thermally bent cover on the original design was deemed to not be the best option. Safety features were also added such as a cover that encases the testing area. A safety switch was also added so that the machine will not run unless the cover is completely shut. This feature was added because the large increase in rate of rotation of the test sample. Further discussion of the new design will be covered in more detail in Section 4.

3.4.1 Safety

Because of such an immense increase in the speed, we felt that it was necessary to add a shield to cover the testing the area. When the wire breaks at that high of an RPM, there is potential for the broken sample to be launched in to the air. The shield will prevent the broken sample from coming into contact with the operator. To ensure that the machine can only be running when the shield is down, a safety interlock switch was added. The system will not start running unless the shield is completely shut. Having it totally shut, completes the circuit allowing the machine to run at full functionality. Pictures of the shield and the safety switch can be seen in below.

3.4.2 Packaging

The overall packing of the system was one of the major components that changes from last semester to this semester. The original design consisted of a thermally formed plastic cover. One of the main reasons that the formed cover was not chosen is because of cost. Fort Wayne Metals wanted this design to be able to be repeated and this style cover would make the production of multiple machines more expensive and difficult. The new design consists of a frame made of 80/20 with a rigid Marine Grade HDPE Polyethylene. Making the frame out of 80/20 made the construction of the system much easier. It also allowed us to make necessary adjustments during the building process. A rendering of the frame can be seen in Figure 4.1.

3.4.3 Rail Mounting Bracket

Because the overall packaging of the system had changed, it was necessary for us to change how the caliper would be mounted. The old design consisted of taller brackets that were mounted to the base of the machine. The thought behind these was to slide the rail into the brackets then fasten it down. With the new design, having the frame made out of 80/20, allowed us to more efficiently use the vertical space because of the versatility of the 80/20. The new brackets are a two piece design. The main part of the brackets are fastened to an upright post of framing on both sides. The rail is placed in the cavity of the bracket and top piece is then put in place to keep the rail from moving. With the design of the old brackets, the hole for the rail to fit into was not a thru hole. After collaboration with the guys from Best Parts, they informed us that having a thru whole would make the part easy for manufacturing as well as cheaper. A picture of the bracket can be seen in Figure 4.4 below.

3.4.4 Wire Support Towers

The wire support towers were redesigned because of economical and manufacturing issues. The original design consisted of a somewhat complex design for the head of the support. It would have also consisted of having to machine the base of the stand. The new stand is much more simple and easy design but equally as effective in functionality. With the new design, we eliminated the need for a machined base by utilizing the rubber coated magnet as the base. A plastic threaded rod was screwed through the magnet where a round plastic bushing is then threaded onto the rod. The bushing has a groove cut into to it to support the wire. This stand is easily adjustable up and down for cases in which the bath is being used.

3.4.5 Carbon Brush Mounting Bracket

Also because of the change in the overall packaging of the unit, the bracket for the break detection also had to be redesigned. The old bracket was designed to mount directly to the thermally formed cover. As stated above, this cover was not utilized, so the 80/20 was used to mount the bracket for the carbon brush assembly. The bracket is located just to the side of the spindle chuck to allow for the carbon brush assembly to come into contact with the shaft. One advantage to the new design is that the bracket can be moved are adjusted as the carbon brushes wear. Figures of the carbon brush bracket and assembly can be seen in Figure 3.3.

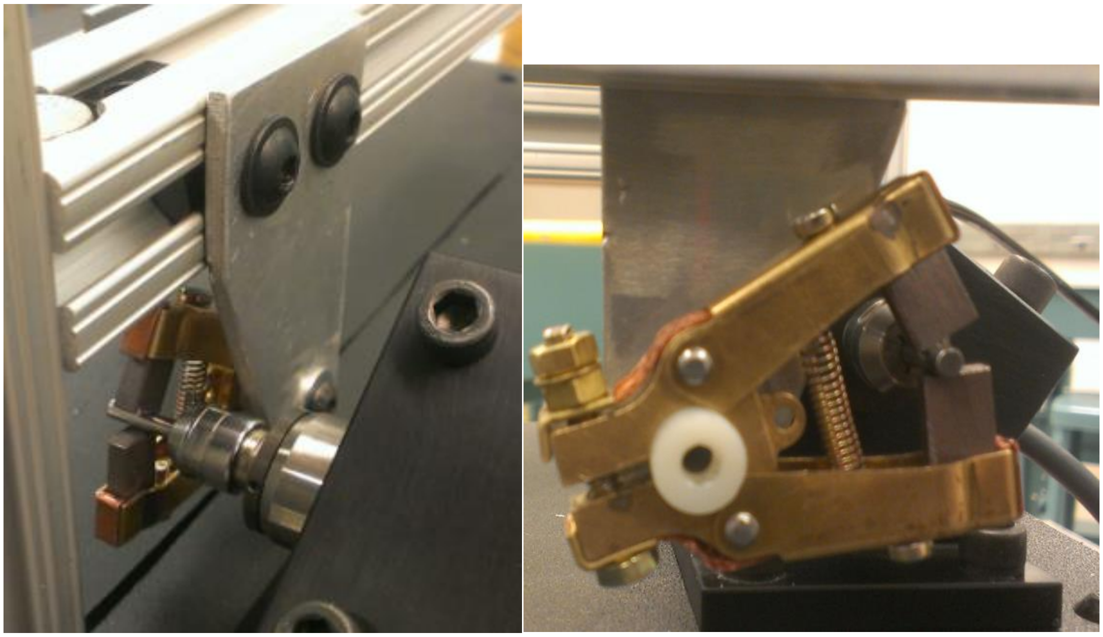

Figure 3.3: Front & Rear Views of Carbon Brush Assembly

3.4.6 Water Bath

No major changes were made to the water bath with the exception of excluding the inlet hole for the water to flow in. Fort Wayne Metals supplies the solution bath through a spout that fills the bath in from the top. The only thing we are concerned with is the flow out of the bath.

3.4.7 Shock Absorbing Feet

One of the biggest concerns during this entire project has been the vibrations created while the motor is spinning at such a high RPM. To help this problem, we added shock absorbing feet, shown in Figure 3.4. These feet will help to minimize the effects of the vibration on the motor turning that may possible have an outcome on the wire as it is being tested.

Figure 3.4: Vibration Absorbing Leg

3.4.8 Final Design

After applying all the changes that are listed above, in this final design the wire is placed and tightened down in the chuck. The other end of the wire is then placed in the brass bushing that is connected to the calipers. The operator would then set the arc distance by moving the integrated caliper to the desired measurement. After the safety shield is closed, the operator can then use the user interface to input the number of cycles they would like the test to run and the speed at which they would like the test to run. After all the inputs have been selected the motor will slowly ramp up to speed to the desired RPM. The test will run until it has met the number of cycles that was inputted or until the test specimen breaks, whichever occurs first.

4 Design Evolution & Component Alterations

In every engineering project that begins as a conceptual design which progresses from scratch paper ideas through production, the design iterations not only change through the final conceptual design, but they must also be corrected once production is factored in based upon material and manufacturability available for the given design. As of the end of last term, our team had a solid conceptual design which we were going to continue through prototype stages with, but certain components warranted redesign once the physical limitations of the materials we had at our disposal made their problems apparent. The “final design” posed merely hypothetical until the team had physical parts in our possession and could analyze the unseen issues that design engineers often fail to see in the disconnect between design and production departments of any engineering group.

4.1 Housing

The first step we took to build the physical prototype was to build the frame, which consisted of a base plate and spindle compartment. The original design consisted of a ¼” thick HDPE flat base and thermoformed compartment. We decided to reevaluate this design due to the difficulty in making the compartment on this prototype and any subsequent builds that Fort Wayne Metals may attempt. During the reevaluation process we uncovered additional initial design flaws. First, the initial design would make it very difficult to implement safety measures, such as safety switched and lids. Second, the base did not have adjustable legs to ensure that the test surface would be horizontal. Additionally, the lack of legs meant that there would be no vibration isolation between the machine and the table that it sits on. This could lead to chattering sounds and the possibility of the machine ‘walking’ across the table.

We decided to scrap the initial base and compartment design. The new design required the frame to be built from an aluminum T-slot extrusion typically used for safety cages and small machines in industry. For our projected we decided to use an extrusion made by 80/20, Inc. The base thickness was increased to ½” and would be bolted to the 80/20 frame. The compartment would be constructed of 80/20 posts and 1/8” thick clear Lexan. 80/20 offers economy adjustable footpads with vibration isolating rubber contacts. Additionally a hinged safety enclosure will be made from 80/20 and Lexan and attached at the top of the compartment posts. The new frame design can be seen in Figure 4.1 and Figure 4.2.

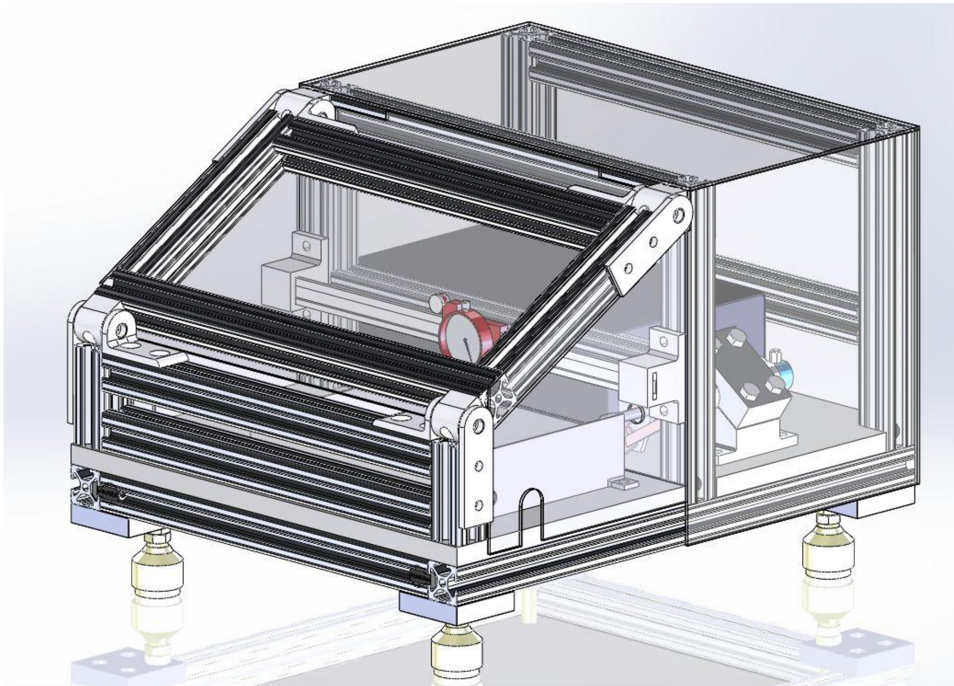

Figure 4.1: Isometric View of Prototype Model (Closed Position)

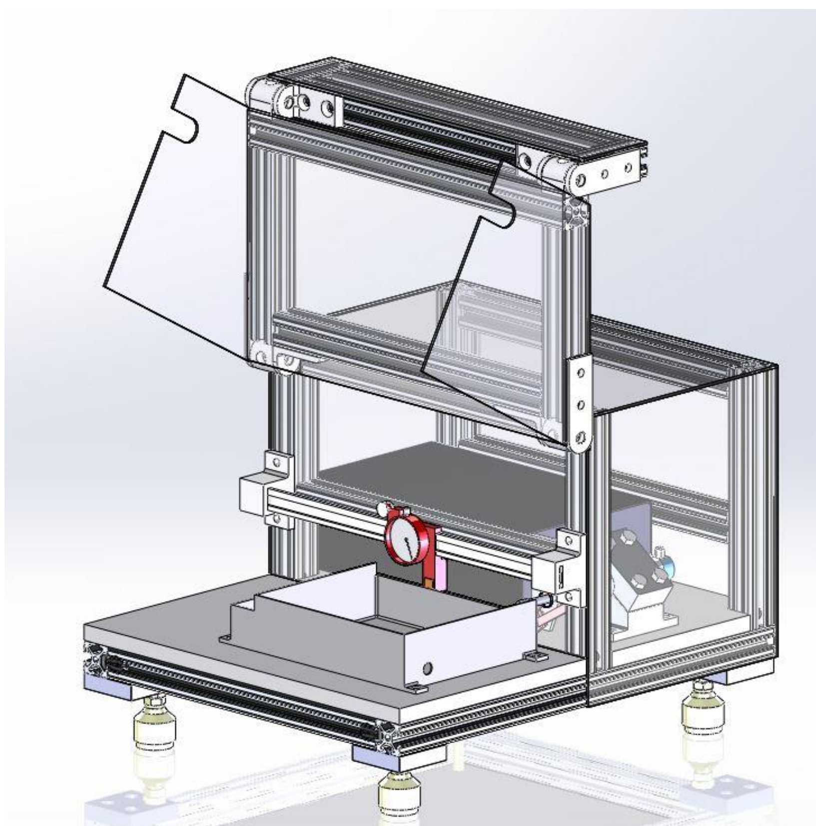

Figure 4.2: Isometric View of Prototype Model (Open Position)

4.2 Integrated Caliper, Rail, & Bushing

Probably the one component that was extremely theoretical in design stages was integrating a dial caliper and bushing as to eliminate the need for external measurement devices to determine the arc dimensions of the test sample. The caliper would already be calibrated for adjustable arc sizes and have an internal bushing which would be electrified as to complete the break detection circuit. The hypothetical finalized designs described a copper bushing, manufactured from copper rod stock with a small hole drilled out for the test sample wire to free spin within the bushing thus completing the circuit. A major constraint that was factored in was electrically isolating the bushing from the steel caliper itself as not to have electrical current openly running through the entire caliper, rail, and any other conductive (metal) parts connected to those parts.

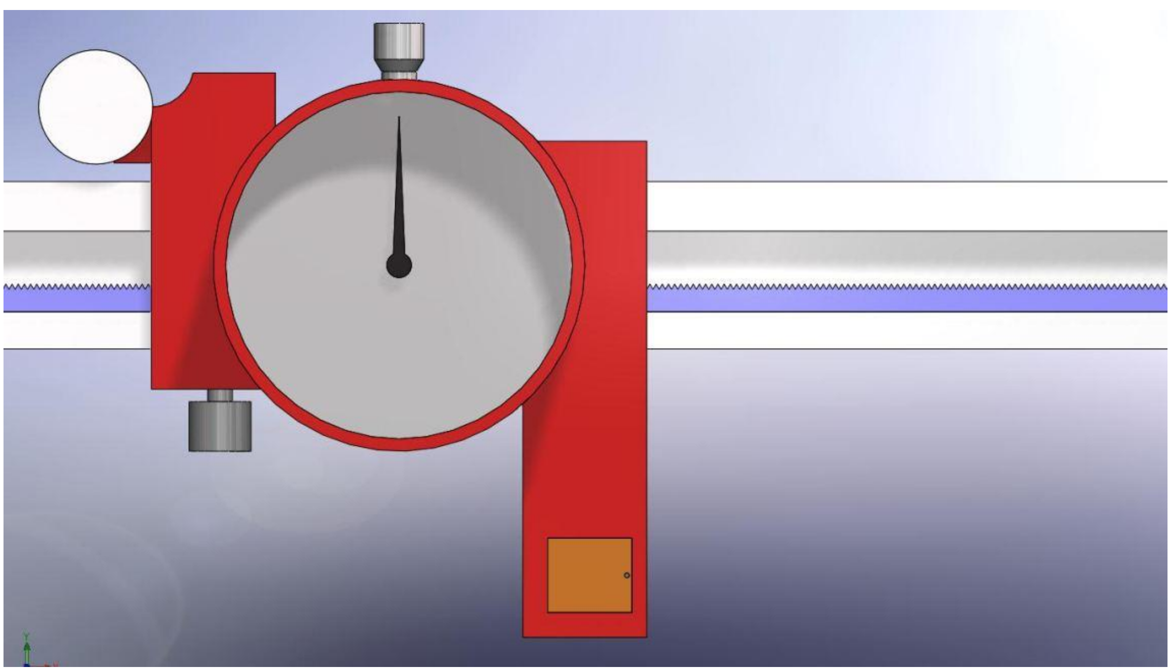

Figure 4.3: Final Caliper / Bushing / Rail Conceptual Design

After investigating different methods to achieve a working bushing while keeping a professional appearance for the end prototype, it was decided to use a small brass screw shaft with a .5" deep hole bored through the center of it, serving as the bushing. The brass would be more corrosion resistant than copper while keeping solid electrical conductivity properties for break detection purposes. The brass shaft would then be placed (screwed) into a nylon screw as to isolate it from the surrounding hardened stainless steel caliper parts and then attached to the caliper itself.

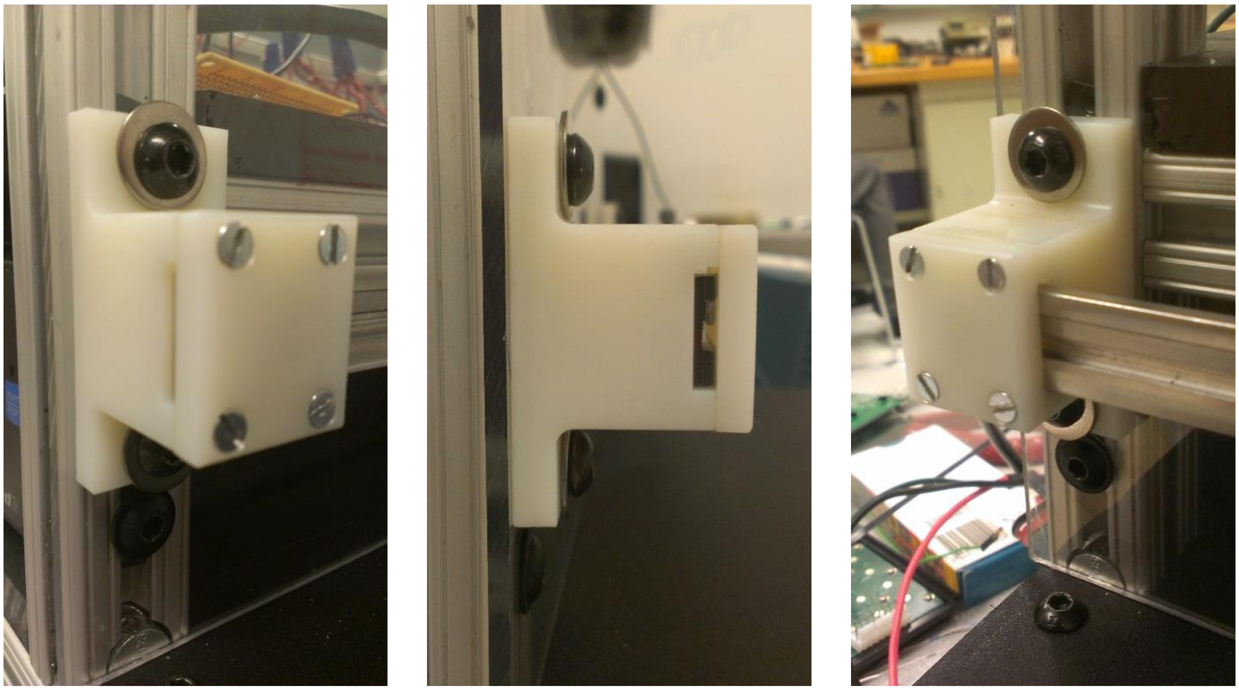

Figure 4.4: Various Views of the Rail Mounting Brackets

In terms of manufacturability, major obstacles experienced with these components were machining difficulties. Between utilizing brass for the bushing itself and purchasing a caliper which was made of hardened steel, both posed extremely difficult to drill out. In ideal conditions, a diamond tip bit would be used to drill both metals out, but given the resources available, carbon bits and drill presses were used which still did not achieve optimum results.

For the brass bushing, design intent was to drill a 1/32" diameter hole through the center of the 1/8" wide shaft as too accommodate all gauges of wire that would be tested with our prototype yet not have too wide of a bushing that causes electrical contact issues while the varying gauge wires are free spinning within the bushing and attempting to complete the open circuit for break detection purposes.

Issues quickly arose with design intent since drill bits of 1/32” size would quickly wear out and often break in drilling attempts so the bore settled on was a 1/16” diameter in attempt to eliminate manufacturing constraints.

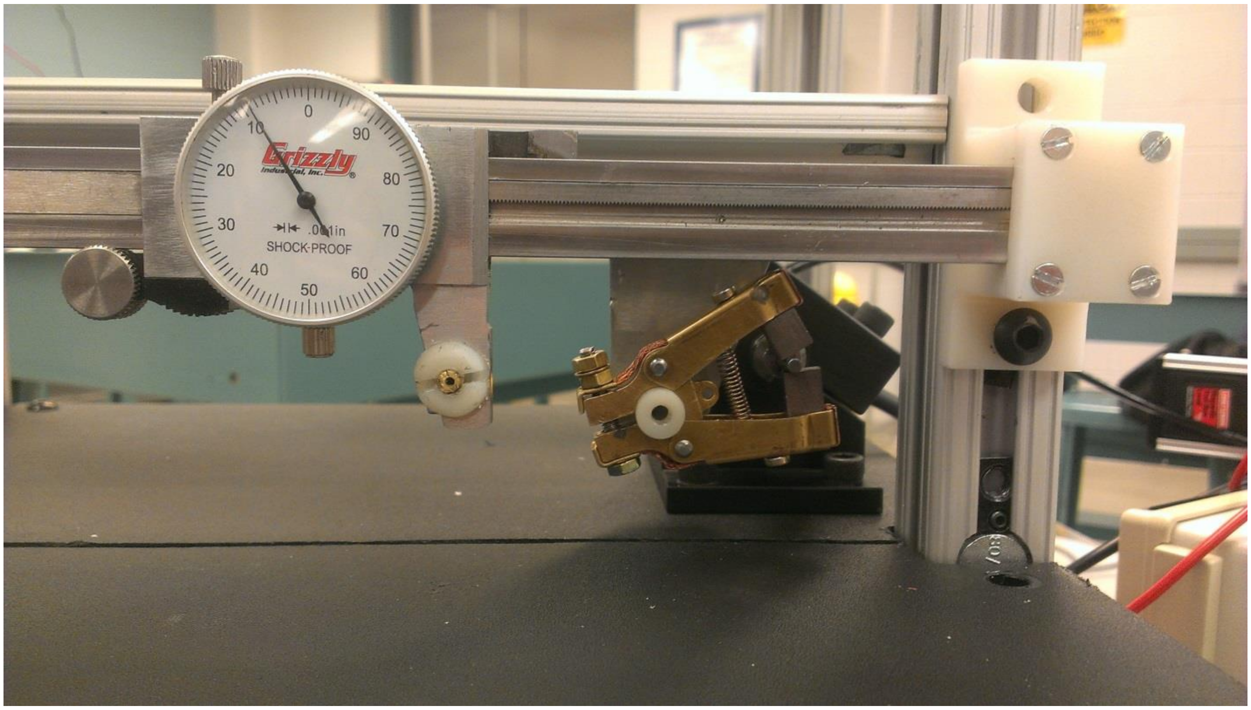

Figure 4.5: Front View of the Caliper / Rail / Bushing

Likewise, for the hole needed in the caliper itself to mount the brass bushing / nylon isolator, it became extremely evident that drilling through the hardened steel which the purchased caliper was made of, would prove problematic. Attempts were made with a various combination of carbon drill bits, handheld drills, a Dremel tool, and a drill press with little to no success until it was decided best to use a diamond cutting wheel to notch the mounting location rather than fail in attempts to drill out the mounting hole.

The rail in which the caliper was mounted on was another hypothetical / un-finalized design that the team knew would need more investigation into purchasable products versus what needed to be custom manufactured. In the finalized prototype, both the dial caliper and rack which drives the dial pinion component in the caliper were purchased parts from an industrial tool manufacturer. Since the mounting location of the motor and controls warranted a left handed caliper (given the direction of spin the dial must spin when adjusted in reference to the stationary motor location) the left handed dial was purchased separately from the 12” rack, but was verified to have identical rack / pinion profiles to maintain proper calibration and measurements. The rail itself, however, was not identical between the left handed caliper and 12” caliper rack / rail, even though communications between the team and industrial company indicated all parts were interchangeable. Due to the unforeseen issue, a custom 12” rail was independently manufactured by Best Parts; then the rack and caliper were mounted to it. Likewise, simple nylon rail brackets were also machined as to mount the entire set of components to the machine itself.

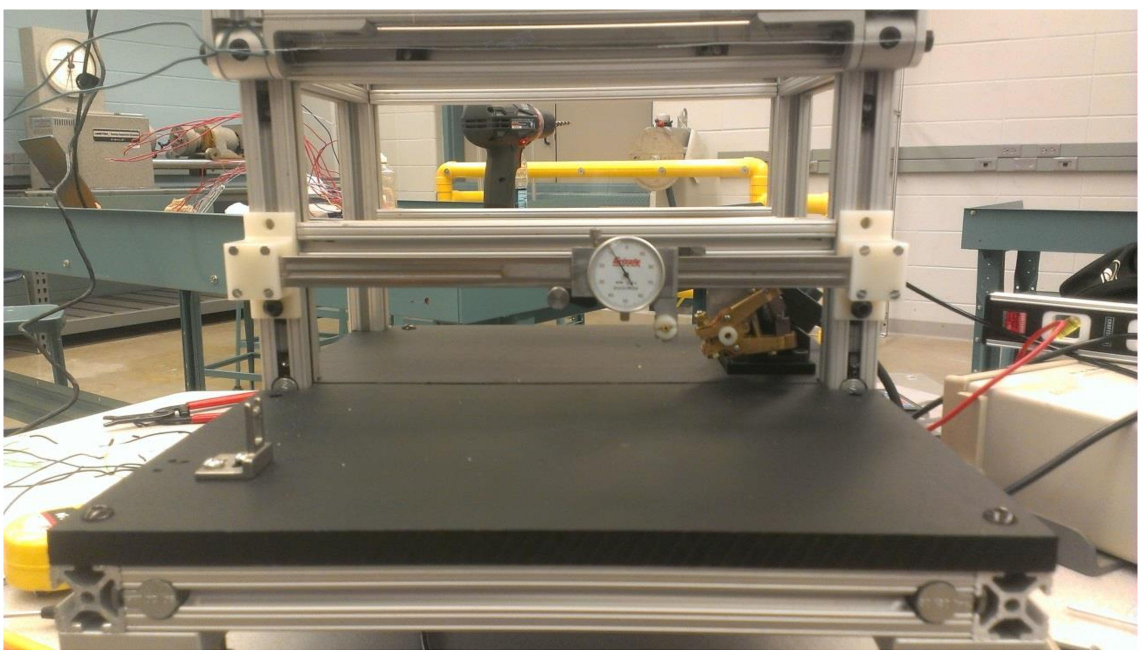

Figure 4.6: Full Front View of the Prototype (Without Controls)

4.3 Removable Bath

One of the only components which remained unaltered between final conceptual designs and manufacturing was the removable bath, used for wet testing sample gauge wires in a submerging of water or saline solutions. The bath itself was intricately designed with considerations to the variable arc sizes required, the flow rate which Fort Wayne Metals utilizes in their standalone water pumps, as well as the meniscus of water over the first wall of the bath in which the test sample lies in. Since the importance of this part in terms of machining tolerances, it was decided to set aside a larger portion of the budget to have it rapid prototyped as to eliminate any machining defects and keep a tighter tolerance.

The bath was prototyped using a selective laser sintering (SLS) method from a nylon material which would properly contain the solutions without chemical reactions. Certain unexpected problems should always be factored in scheduling a project's progress calendar since, whether purchasing or manufacturing a component, one can never know what unseen issues will arise and affect the date of completion. After shipping, the prototyped bath that was received from the rapid prototype company was incredibly warped due, most likely to, material shrink rates in post-production once the part cooled from being printed. The company was contacted and another part was shipped after being properly quality checked prior to shipment, but the situation is a prime example of not achieving set dates due to unforeseen circumstances.

Figure 4.7: Warped Bath Prototype (Isometric View)

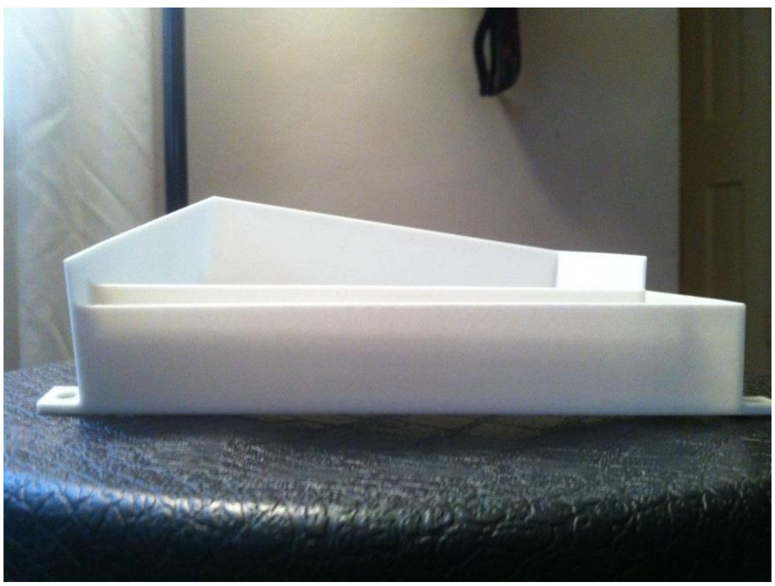

Figure 4.8: Warped Bath Prototype (Front View)

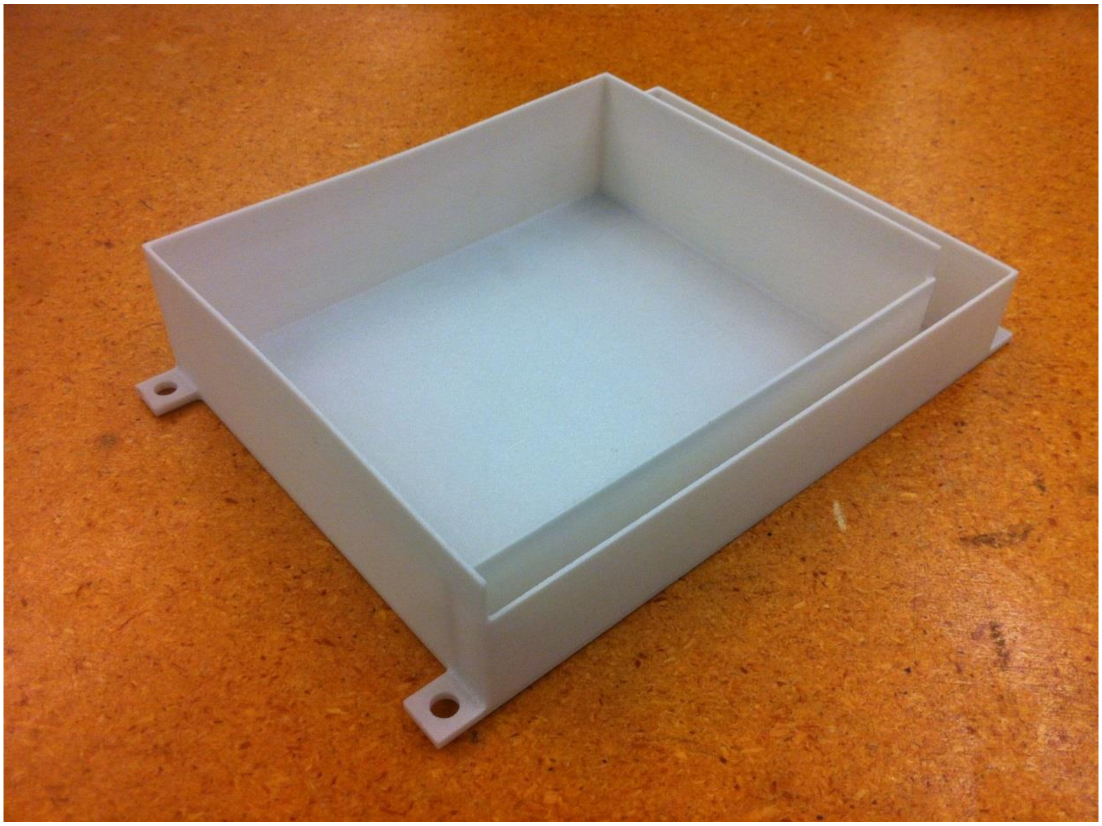

Figure 4.9: 2^{nd} Fixed Bath Prototype

4.4 Chuck & Shaft

Using pin vises purchased from Starrett, the chuck components of the actual handheld tools were machined off from their original shafts, then tapped in order to screw onto a custom drill shaft. This new shaft and chuck combination then gets inserted into the stock iSpeed 3 motor chuck.

Figure 4.10: Disassembled Chuck & Shaft

Figure 4.11: Assembled Chuck & Shaft

4.5 Programming

The programming environment that was used was Arduino's IDE version 1.5.2. This was the latest version of the IDE and it was need to interface with the Due because it was a new product. This environment has two built in functions: setup() and loop(). Setup() is code that is only run once while the microcontroller is powered. This function was used to initialize the I/O pins, setup the serial port, and create the keypad class that was used to represent the keypad. The loop() function is used to run the main in code in the form of a super loop, a basic real time operating system. This function was used to call the first function in the process and then each of the functions called each other as they needed to continue the code. The code can be broken down into two different sections. The first section if the initializing of the test parameters. All the editable parameters for a test are the number of cycles need to achieve a run out status, the speed that the test will be run at which can be anywhere from 1000rpm to 80000rpm, and whether or not the break detection and the case open detection is turned on or off. Once those parameters have been input the program waits for the user to begin the test. Once the test begins the last section of the code begins. The code then sends several signals to start the test and begins to monitor several inputs: when the case is opened, error is detected in the motor controller, the user indicates that they wish to pause the test, when the wire breaks, and a pulse coming from the motor controller that each pulse represents one revolution of the motor so that the number of cycles can be counted. For the first three the program pauses the test until the specific condition has been lifted. For the last two it ends the test and displays the number of cycles that the wire completed. Once a test has been ended it awaits input from the user to go back to the beginning of the process to start a new test.

The coding was broken down into various functions to make it easier to repeat certain sections of code and to allow the ability to jump to various sections of code when needed. Also it made it easier to isolate error because a debugger was not used. The built in Arduino functions made accessing the I/O pins and various other microcontroller operations easy. Only one problem was not able to be solved with their code. The LCD uses RS232 protocol to communicate and it requires two stop bits. The provide Arduino functions do not currently support changing the number of stop bits from one to two for the Due. So to solve the problem a change was made to the included header files that control the serial register settings.

4.6 Controlling

The microcontroller was used to control a keypad, LCD, and the motor controller. To do that it needed to make use of several digital logic I/O’s and a serial port. The motor controller made use of several I/O’s. They were used to control what motor is being controlled, when to start and stop the motor, when to speed up and slow down the motor, when an error has occurred, and a pulse that represents one revolution of the motor. The LCD display used RX line from the microcontroller with eight data bits and two stop bits. The keypad was a 4x4 matrix style keypad pad and made use of eight I/O pins to determine which button was pressed on the keypad. Also the microcontroller needed two inputs for the break detection and the case open detection.

Because the microcontroller’s digital logic high was at 3.3V and the LCD’s was at 5V and the motor controller was at 12V digital level shifting was needed to adjust the logic levels so that they would be appropriate to which every device they were going to. There was a level shifter that went from 3.3V to 5V for the microcontroller to the LCD, one from 3.3V to 12V for the microcontroller to the motor controller, and a 12V to 3.3V for the motor controller to the microcontroller. The break detection and the case open detection used 3.3V so that no level shifting was need to interface with the microcontroller.

4.7 User Interface

The user interface was kept simple by using only a keypad input and a LCD to display the information. The keypad had the numbers zero through nine and made use of the Clear and Enter buttons. The LCD was a 4 by 20 character display. The display would ask for the user to input information using the keypad. For the speed and cycle input the LCD would display the information that the user input. After each section of parameters being input the interface would have the user confirm the information that was input so that any mistake that had been made could be corrected. During the running of the test for interface displays the current cycles that have been run and allows the user to pause the test by pushing the Clear button.

Figure 4.12: User Interface Menu Screenshot

5 Testing & Analysis

5.1 Mechanical Test Parameters

- Chuck Functionality
  - The custom fitted chuck will be tested for all ranges if wire that will be tested by the device. This includes functionality of gripping power during an active test as well as centripetal balancing.
- Corrosion Resistance
  - All seals between assembled pieces of the machine's covering will be tested to verify their ability to resist leaks into the electronics control cavity.
- Motor Security
  - The security of the motor mounts will be tested to verify their dissipation of any motor vibrations during the test without damage to the motor, spindle, or any surrounding components.
- Electric Brush / Electrified Bushing Functionality
  - Verification that current passes through the test wire for accurate break detection purposes will be necessary.
- Bath Design
  - The bath will need to be inspected in terms of dimensioning and functionality for all ranges of test sample arc dimensions.

5.2 Mechanical Testing Procedure

This section will list out the detailed testing procedures that were performed during the semester to verify the functionality of the system.

5.2.1 Chuck Functionality

1. Gathered samples of wire at the following sizes:
    a. .001”
    b. .007”
    c. .015”
2. Placed each size of wire in the chuck and powered motor up
3. Verified that the chuck clapped down enough to spin each size wire

5.2.2 Motor Security

1. Place air spindle into motor mount
2. Power up the control unit
3. Clamp motor down into the motor mount
4. Tighten motor down until the appropriate resistance value is displayed on the control unit
5. Power up air spindle

5.2.3 Electric Bushing /Carbon Brush Functionality

1. Place each size wire in the chuck as well as the bushing side
2. Electrify the wire at each size
3. Place multi-meter on wire to see if the wire is conducting electricity at each size

5.2.4 Bath Design

1. Place ranges of wire in the machine
2. Verify that the water flow into the bath is enough to cover each size of wire
3. Verify that the water flow at the exit of the bath is enough to keep water level constant

5.3 Mechanical Test Results

5.3.1 Chuck Functionality

When we conducted the test procedure for chuck functionality we found that the 0.015” and 0.007” diameter wires were easily clamped by the chuck. The 0.001” diameter wire required a small plastic bushing in order for the chuck to clamp onto the wire with enough force to spin it. The use of the plastic bushing renders the break detection system useless. We expanded the test procedure to include 0.003” diameter wire. This size seems to be the transition point where using the plastic bushing is required.

5.3.2 Motor Security

The motor security procedure was performed per section 5.3.2 and the manufacturer’s instructions. The spindle never moved during any testing, therefore it is secure.

5.3.3 Electric Bushing / Carbon Brush Functionality

We tested the 0.007” and 0.015” diameter wires for static conductivity between the carbon brush and the brass bushing. When each wire past the static test we powered up the spindle and performed the same conductivity tests. Both wires passed for all speeds. The smaller wires which require a plastic bushing were not tested since the automatic break detection system will not work with the use of plastic bushings.

5.3.4 Bath Design

We tested the maximum flow rate of that the system could handle before the lower drain section of the bath over flowed. At the maximum flow rate the flow meniscus was approximately 1/8”, which is way more than necessary to submerge the test specimen. Additionally, we measured the final test area of the bath to ensure a 6” center distance and 5” arc heights were achievable.

5.4 Electrical Test Parameters

- The User Interface
  - It will be tested by giving the user's manual to someone unfamiliar with the project and they will attempt to navigate the user interface. This tested will be passed when the tester feels the user interface is easy to navigate and does not cause any errors to the system.
- Motor Speed Control
  - Several different motor speed signals will be sent to the motor controller one at a time. Then a tachometer will be used to verify that the motor is operating at a speed reasonably close to the speed programmed into the microcontroller.
- Blackout Condition
  - The machine will be left running for a short time and then power will be removed from the input. Then we verify that the motor stops moving and measure the amount of time that the uninterruptable power supply is able to supply power to machine before it shuts off. Also the test will be repeated but power will be resupplied to the UPS once it has been verified that the motor has shut down to make sure that the test starts back up properly after it has sustained a power loss.
- Break Detection
  - The machine will be operated normally and when the wire breaks we will check that the microcontroller stops the test and displays the appropriate information.
- Reliability for a Period of Time
  - The machine will be tested over a week's worth of time to make sure that it is able to operate for extended periods as it will be at Fort Wayne Metals.
- Error Signal
  - The machine will be operating normally and then various error situations will be applied to make sure the microcontroller handles them properly.

5.5 Electrical Testing Procedure

5.5.1 The User Interface

1. Had people not familiar with the programming and design run a test
2. Had them evaluate the use of the interface

5.5.2 Motor Speed Control

1. Used the interface to set the speed for a test
2. Verified that the programmed speed matched the speed on the motor controller

5.5.3 Blackout Condition

1. Charged the batteries on the UPS until they were fully charged
2. Began a long test on the machine
3. Removed the power to the UPS
4. Used a camera set to take a picture every minute to watch the machine
5. Left running until the UPS ran out of power

5.5.4 Break Detection

1. Began a test with a wire in the tester
2. Pulled the wire out of the bushing
3. Verified that the test stopped when the wire was removed

5.5.5 Reliability over a Period of Time

1. Began a long test on the machine
2. Left running for several hours to verify that the performance did not change of time

5.5.6 Error Signal

1. Began a test on the machine
2. Shut off the air to the machine to create an error situation
3. Verified that when the error occurred the test was paused

5.5.7 Case Open

1. Began a test on the machine
2. Opened the case while the test was running
3. Verified that the test paused while the case was open

5.6 Electrical Test Results

5.6.1 The User Interface

We had several people start a test with the machine and got their opinions of the interface. All of then thought that the presentation of the information was good. That the keypad input was easy to used and preformed as expected. The confirmation of inputs was liked because it allowed for the user to make sure that they had input the correct information.

5.6.2 Motor Speed Control

In every speed that was tested the motor controller would so that the motor had achieved the programmed speed and did not go over or under the speed when the starting speed was 1000 rpm. Also as long as power is not removed from the device it returns to 1000 rpm at the end of the test.

5.6.3 Blackout Condition

The machine was test according to our procedure but a malfunction in the camera prevented knowing how long the machine ran under battery power. It was reported that the machine was still running 7 hours after the test was begun and Fort Wayne Metals said that it was acceptable.

5.6.4 Reliability Over a Period of Time

This was tested at the same time as the Blackout Condition. The machine ran for at least 7 hours without any malfunction. This met our overnight test condition. There is no evidence that they will be any problem with the machine running for long periods of time. The maximum number of cycles that can be input is 2000000000. At 80000 rpm it would require 17.5 days to complete that test.

5.6.5 Error Signal

4 seconds after the air supply was removed from the machine the motor controller reported an error. The test stopped and the LCD reported that an error was reported. When air supply was restored the Enter button was pressed on the keypad and test resumed where it was when the error occurred.

5.6.6 Case Open

During the running of a test the case was opened the microcontroller paused the tested and reported that the case was open. When the case was close the test resumed its operation.

5.7 Data Validation

Given the current testing procedures that Fort Wayne Metals utilizes and the limited capabilities that their current machines can achieve, a large question is how to validate test data between the old machine and new prototype. Currently, the wire fatigue testers run at 3,600 RPM to which, the tests being conducted, are measured in duration of cycle count associated with that speed. The new machine, however, has the ability to run at 80,000 RPM max speed, varying in 100 RPM increments while utilizing an open circuit break detection in which current is run through the test wire. The change in design components and functionality of the tests has a large impact on correlating data between the surplus of previously conducted tests with the old machines to the new machine.

5.7.1 Heat Generation

A certain amount of heat is generated by air friction when mass is in rotation due to the kinetic increase in energy and therefore either propagation of heat and / or noise. The amount of heat generated increases proportional to the speeds at which the test samples are rotating therefore, increasing the variable speed from a steady 3,600 RPM to a maximum achievable speed of 80,000 RPM which is a +2000% increase in speed, will affect the test sample’s life span in terms of cycle count since heat directly affects the strength of metals while in stages of tension and compression. Given this factor of air friction heat generation while the sample is being tested, one can assume a disconnected in correlating the new test data with the older test data (at constant 3,600 RPM speeds) since there is a major change in testing conditions across the spectrum and added factors of the environment in which the tests are conducted.

5.7.2 Current & Corrosion

Since a current is now being run through the test sample for the open circuit break detection, an added factor was raised of whether this would increase the rate of corrosion while submerged in wet test conditions. To validate the possibility of added corrosion due to a change in environmental factors, a simple test was conducted in which two identical 0.06” diameter wires were submerged in a 300 mL solution consisting of 1 teaspoon of salt. One test sample was submerged with no electrical current while the other had 0.275 amps of constant current running through it for a two week duration. At the end of the experiment, there was no measurable difference in corrosion rates between the samples which led to the conclusion that, if there is any added rate of corrosion due to the current running through the test samples, it is a negligible amount which will have no valid effect on future tests.

Figure 5.1: Corrosion Resistance Test Under Constant Current Conditions

6 Evaluation of Deliverables

In the evaluation of the wire life cycle tester, the main focus was to evaluate how our design met the requirements set for us by Fort Wayne Metals. The biggest goal our team had to meet was a max speed of 100,000 RPM. After much research and discussion with experts in the field, it was determined that a speed this high while maintaining reliability would be nearly impossible. The final design allows us to run the machine at 80,000 RPM in a reliable manner.

Another goal of Fort Wayne Metals was to be able to adjust the center distance of the test specimen in a more accurate way without having to use an external measure device. This was accomplished by integrating a caliper into the design that allowed for a real time measurement.

Break detection was also a major part of this design. We were able to determine a break in the wire by electrifying the test specimen. When the specimen breaks, so does the current in the wire; which turns the machine off and displays how many cycles the wire went before it was broken.

The tester was also improved by taking advantage of a user interface. This user interface allowed for the operator to input the speed , the number of cycles, and the option for break detection.

After evaluating all the goals set by Fort Wayne Metals, it was determined that we met the requirements of the project. We were able to decrease test time by 95.5%, design a user interface for ease of operation and easily adjust the center distance measurement without an external measure device.

7 Conclusions

In conclusion, the wire life cycle tester was able to be implemented with a few deviations from the original design. The main function of the machine was maintained, while making changes to the overall packaging. The driving force behind these changes was manufacturability, cost, and quality. It was found after testing that the machine was able to output accurate results while functioning within the constraints given by Fort Wayne Metals. The wire life cycle tester was able to run at a high speed while using the integrated calipers to change the center distance measurement. The tester also provided a user friendly interface as well as safety features such as the cover over the testing area and a safety switch that will not allow the machine to run until the coving is completely closed. The final assembly was tested and approved by the Fort Wayne Metals engineering staff and the project was deemed to be a success. Fort Wayne Metals was very pleased with the prototype and plan to use it in the near future.

8 Budget

Dept.	Item Description	Qty	Cost
ME	iSpeed3 system with BM320 spindle	1	$4,065.00
ME	80/20 ordered through Andrew Hill	N/A	$173.56
ME	80/20 ordered through Neff Engineering	N/A	$106.76
ME	Carbon Brush Holder	1	$92.50
ME	Material for carbon brush bracket	1	$1.94
ME	HDPE Polyethylene Marine Grade	1	$50.85
ME	Key Actuated Access Safety Switch, 5 Amps	1	$71.30
ME	Miniature 12L 14 Drive Steel Shaft, 1/4"	1	$9.70
ME	Bath Prototype	1	$588.34
ME	Miscellaneous Mechanical Components	N/A	$210.34
EE	UPS Cyber Power 1500AVR	1	$289.82
EE	@ 40 Watt LPT41	2	$119.21
EE	10 Watt NFM 10~Series	3	$54.97
EE	Arduino Due Atmel SAM3X8E ARM Cortex M3 CPU	3	$163.65
EE	Devantech LCD03 4x20 LCD Screens	2	$93.19
EE	ACT-07-30008-000 Keypad	2	$37.28
EE	REV3 782-A00080 Proto Shields	2	$29.00
EE	MC4504BCPG Level Shifters	12	$9.60
EE	Multipurpose PC Board	5	$5.00
EE	Miscellaneous Electrical Components	N/A	$238.78
	Total Expenditures		$6,410.79
	Budget Allowance		$10,000.00
	Amount Under Budget		$3,589.21